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Corrigendum

Corrigendum to “A framework proposal for sustainability assessment of sugarcane in Brazil” [Land Use Policy 68 (2017) 597–603]

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A R T I C L E I N F O

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A B S T R A C T

In many countries the biofuel sector was encouraged to expand its activities, supported by public policies incentives, with the main aims to improve energy security and to reduce greenhouse gas (GHG) emissions. The Brazilian government followed these initiatives and undertook its responsibilities considering the international consensus related to the need to mitigate climate change. One of the theses commitments concerned actions to reduce the GHG emissions by 37% in 2020. The Sugarcane Agroecology Zoning provides technical support to policy makers in order to direct sugarcane expansion to permitted areas. It is considered a guideline to achieve sustainable sugarcane production in Brazil. However, although the zoning aimed at sustainable production, it only considered natural aspects of the country, as soils and climate. Currently an approach that considers all three dimensions of sustainability (environmental, economic, social) is still missing. This paper proposes a framework to evaluate biofuel sustainability to support public policies, especially concerning improvements in Brazilian decision-support tools.

1. Introduction

Supported by incentives and policy measures, such as Directive 2009/28/EC of the European Parliament and of the Council, the Cramer Certification, the Renewable Transport Fuel Obligation (RTFO) and others, global ethanol and biodiesel production are both expected to expand to reach, respectively, almost 134.5 and 39 billion litres by 2024 (OECD/FAO, 2015). Thus, sustainable biomass for biofuel production from agricultural crops continues to ignite debate on sustainability (Buyx and Tait, 2011; Florin et al., 2014). These discussions often revolve around the three dimensions of sustainability (environmental, economic, and social), their trade-offs, how these trade-offs should be analysed, and hence how the relative importance of the underlying dimensions should be valued. The concept of trade-offs (rather than that of the common discourse on win-win situations) stresses that the system cannot be maximised for sustainability in all these three dimensions (Kuyper and Struik, 2014). While systems can be optimised for some dimension, it needs a political process to balance environmental, economic and social sustainability.

Biofuels are a complex system that includes the social, economic and environmental sustainability domains (Mangoyana, 2009). Academics, state governments, government agencies, non-governmental organisations, and international agencies seeking to identify the key sustainability issues in biofuel developments have produced many publications providing insights into the social, economic and environmental issues related to the development of biofuel systems. Notable contributions include the UN-Energy (the interagency formation on energy under United Nations; UN-ENERGY, 2007), the United Nations department of Economic and Social Affairs (UNDESA, 2017), the World Wildlife Fund, the German Federal Ministry for Economic Cooperation and Development (Fritsche et al., 2006), and the EU *Proposal for a directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources* (European Commission, 2008).

Sustainability criteria for biofuels are currently being developed, implying that:

- A certain percentage of greenhouse gas reduction should be attained compared to the use of fossil fuels;
- Competition with food should not endanger food security and other local applications of plant biomass, e.g. medicines;

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- Protected or vulnerable biodiversity may not be affected;
- The quality of soil, air and water must be sustained;
- Biofuel production must contribute to local welfare;
- Biofuels must contribute to the well-being of employees and local population (Bindraban et al., 2009).

This list summarises the sustainability issues as it includes the environmental, economic and social aspects. However, the difficulty is to use all of these aspects in an integrative way and, more importantly, to define criteria and find indicators that could show the performance of each aspect. Brazilian et al. (2011) provided a rationale for addressing the nexus in a quantitative manner and presented a modelling framework that could support effective policy and regulatory design. Case studies clearly showed the need for this type of analysis and consequent upon the analysis, the implementation of the required institutional changes. However, Buchholz et al. (2009) noted the lack of clear consensus amongst bioenergy experts and other stakeholders which indicators are critical and mandatory and which framework should become standard practice.

Sustainability is an essentially integrative concept and it has been defined in many ways. The most frequently quoted definition is from *Our Common Future*, also known as the *Brundtland Report* (WCED, 1987): *Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given, and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs*.

Considering the imperative of agricultural production for future generations, one concept championed to produce win–win situations for food production and biodiversity is "sustainable intensification" (Nimmo, 2014). However, Loos et al. (2014) and Struik and Kuyper (2014) pointed out that assumptions of win-win situations are often naive and that sustainable solutions for food security must address issues such as food accessibility, which is a social issue rather than a agronomic challenge. Many authors discussed the sustainability of crop production, including the production of biofuels. For Smyth and Dumanski (1993) sustainable production systems can be defined as *systems that have an economically and socially acceptable, stable production level while natural resources in the ecosystem are protected and soil and water degradation is avoided*. For Mangoyana (2009) the process of establishing a biofuel sustainability framework involves identifying key dimensions, each of them considered critical in the process of understanding the sustainability issues of biofuels, and hence system learning. For Gibson (2006), it seems reasonable, then, to design sustainability assessment as an essentially integrative process and framework for decision-making on activities that may have lasting effects.

The European Union (EU) also pursues sustainability criteria for biofuel production, processing and trade, since the rapid expansion of biofuel production and consumption has raised concerns over social and environmental sustainability (German and Schoneveld, 2012). The Renewable Energy Directive (RED) 2009/28/EC of the European Union includes a set of mandatory sustainability criteria as part of an EU sustainability scheme and monitoring and reporting requirements for biofuels and bioliquids (EU, 2009a). Similar sustainability requirements were set in the Fuel Quality Directive 2009/30/EC (EU, 2009b) on the specification of petrol, diesel and gas–oil and introducing a mechanism to monitor and reduce GHG emissions. Biofuels are required to fulfil all sustainability criteria to count towards EU targets and to be eligible for financial support. The EU Member States are responsible for checking compliance with the sustainability criteria, but the European Commission can recognise voluntary sustainability certification schemes. The EU-RED excludes several land categories, with recognised high biodiversity value, for use for biofuel production: (a) primary forests and other wooded land; (b) areas designated for nature protection or for the protection of rare, threatened or endangered ecosystems or species; (c) highly biodiverse grassland, either natural or non-natural. Biofuels should furthermore not be made from material from peatland and land with high carbon stocks, such as: (a) wetlands, (b) continuously forested areas, (c) land covered by trees higher than 5 m and a canopy cover between 10% and 30% (Scarlat et al., 2011).

To ensure that biomass as a source of renewable sustainable energy is produced and processed in a responsible manner, the Dutch government incorporated sustainability criteria for biomass into the relevant policy instruments. In preparation for the above-mentioned policy, the Dutch government has set up the *Sustainable production of biomass* project group. This work by the project group has resulted in what is known as Cramer's index and it proposes criteria for the production and the processing of biomass in energy, fuels and chemistry (Cramer Commission, 2007). In this regard it does not make any difference if the biomass originates from the Netherlands, from the EU, or from outside the EU. The project group has consistently consulted the different parties involved in order to ensure a broad support base for its proposed policies. For the development of Cramer's index (Cramer Commission, 2007) six relevant questions were distinguished:

- How much emission reduction does the use of biomass yield for a specific producer, calculated from its source up to its use, and compared with the average use of fossil fuel?
- Competition with food and other local applications: Does large-scale production of biomass for energy supply supplant other uses of the land, for example for the cultivation of food or wood as building material, and what are their consequences?
- Biodiversity: Does the local natural ecological system of land and water lose any variation in forms of life because of the large-scale cultivation of energy crops?
- Environment: Are there any effects of the use of pesticides and fertilizers, or are there other local effects on soil, water and air because of the large-scale production of biomass?
- Prosperity: Does the production of biomass contribute towards the local economy?
- Social well-being: Does the production improve the social living conditions of the local population and employees?

Isolated initiatives concerning sustainability of biofuels can also be found in Brazil, but all of them have limitations in quantity, quality and integration of criteria (Goldemberg et al., 2008; Gomes et al., 2016; Machado et al., 2015; Silva Lora et al., 2011). This paper aims to propose a framework to evaluate biofuel sustainability to support public policies, especially concerning improvements in Brazilian decision-support tools. To do so, an extensive literature review was done and fifteen scientists from various disciplines with experience in biofuel sustainability issues were interviewed.

2. Material and methods

2.1. Study case – Brazilian ethanol

Since the concern with Kyoto Protocol targets, the energy matrix and the strategies for sustainable economic development have been at the centre of discussions by experts and global authorities. This new perspective on biofuels has led ethanol into policy agendas, especially in developed countries, like the United States and members of the EU. Bio-ethanol from Brazil is an attractive biofuel because of its low price and relatively large greenhouse gas emissions reduction potential (Buckeridge et al., 2012; Martinelli and Filoso, 2008). By growing sugarcane in order to produce bio-ethanol, the Brazilian government undertook some of its responsibilities to make its national contribution to the attempts to reduce climate change. One of these commitments concerned actions to reduce GHG emissions by 37% by the year 2020 (Brasil, 2009).

Sugarcane expanded in Brazil from 1975 to 2012, increasing 413% in area where the crops is grown. Currently sugarcane is grown on around 7 million hectares. It is important to highlight that in 1975 there was an important public policy to stimulate sugarcane production called *Proalcool*. During the entire period, many public policies were designed but most of them were related to economic (and not to environmental) incentives to sugarcane production. Only in 2009, with Decree 6.961, a public instrument to be used as a guideline for sugar cane expansion was created – the *Sugarcane Agroecology Zoning* (Manzatto et al., 2009) – considered a guideline to sustainable sugarcane production in Brazil. The main aim of *Sugarcane Agroecology Zoning* is to provide technical support to policy makers to direct sugarcane expansion to permitted areas in order to create sustainable production systems in Brazil. Although the scheme was aimed at sustainable production, the zoning only considered natural aspects of the country, such as soil and climate. A further challenge in the Brazilian scene was to increase sugarcane yields on existing farmland, given concerns about the conversion of grassland and rainforest to crop production and the rapidly increasing global demand for sugarcane ethanol (Marin et al., 2016).

Concerning the social pillars of sustainability, very little information is available and therefore this dimension is hardly considered in most sustainability assessments of sugarcane. In Brazil the social sustainability dimension is a politically sensitive case. The typical sugarcane worker in Brazil is a migrant from poor areas in the north-eastern region of the country who moves to the southeast to work for 6–8 months as a sugarcane cutter (Martinelli et al., 2009). These authors emphasised that Brazilian labour legislation is not prepared to deal with this reality. However, increasing pressure from public authorities in Brazil and from the international community is making the ethanol industry recognize that it is not possible to claim that ethanol is a clean or sustainable fuel, when workers are working in extremely poor conditions, are severely underpaid, and worst yet, often die of exhaustion in the fields during sugarcane harvesting (Scopinho et al., 1999; Martinelli et al., 2009; Labruto, 2014). As an example of this effort to change the bleak conditions for sugarcane workers is the initiative called *Lista Suja* (Dirty List) promoted by the Labour Ministry. On that list there are the names of those companies accused of using slave labour in Brazil.

2.2. Experts consultation

This paper is based on an extensive literature review and expert consultation. The study is part of a cooperation project between Brazil and The Netherlands (Coordination for the Improvement of Higher Education – CAPES and The Netherlands Organisation for International Cooperation in Higher Education – NUFFIC). Wageningen University and Research was one of the Dutch institutions that joined this partnership and the experts selected were those who had experience in biofuel sustainability issues at, with different profiles such as: land use planning, landscape ecology, climate change, bioenergy, agricultural policy, food security, economics and knowledge valorization (Table 1).

Based on the mains assumptions of the literature review, an open interview was held with fifteen experts (Table 2), and they were invited to talk about the following six issues: (1) sustainability of biofuels, (2) drivers of sustainable or unsustainable biofuels, (3) integration of sustainability aspects (social, economic and social) and trade-offs, (4) scale and sustainability, (5) multistakeholder involvement and sustainability, (6) direct and indirect impacts of land use change (LUC) of biofuels.

The non-directive interview originates from a technique used to obtain information based on the free speech of the interviewed. It presupposes that the informant is competent to express her or his experience and to manifest in a unique way the historicity of the acts, conceptions, and ideas (Chizzotti, 2005). The interviewer took notes of the comments by the interviewed concerning each subject of Table 2, without interventions. Natural to human behaviour, some interviewees were more receptive and more willing to comment on all subjects, while others were more concise in providing their opinion. A new document was created in the end to transpose the observations of each interviewed topic by topic. The results present the core of each topic, based on the interviews.

In order to make the discussion more stimulating, the nine topics of Table 2 were synthesized in six issues in the following section.

3. Results and Discussion

3.1. Biofuel sustainability

Considering the significant net-energy gains showed by life cycle analyses of various raw materials for biofuel production (Menichetti and Otto, 2009; De Vries et al., 2010; Panichelli et al., 2009; Achten et al., 2008; Reinhardt et al., 2007; Gmunder et al., 2010), we conclude that several different ways to produce first generation biofuel production can meet the net-energy provision criteria suggested by Hill et al. (2006) and as such be considered to be feasible energy options in the short-to-medium term. However, current practices rely greatly on fossil fuels for fertilizers and agrochemicals, so long-term viability of biofuels based on current production practices and technologies is certainly contentious (Filoso et al., 2015). Additionally, there are several other non-energy related concerns that need to be considered, such as competition between food production and biofuels, biodiversity threats, and others. In fact, whether biofuel production and use can have a negative or positive impact on the environment and society depends on several interconnected factors (Gasparatos et al., 2011). About the sustainability of biofuels, there appeared to be consensus among the professionals in this consultation on the following issues:

- Land use change that can be induced by biofuel crops is a discussion point especially because the biggest argument favourable to biofuels, the reduction of GHG gases, could be invalidated because of land use change;
- Competition with food – some arguments include that the land and all the resources that it includes (soil, water, biodiversity, carbon, etc.) should have a more noble use, like food production. There are many others ways to produce energy in a sustainable way like the use of residues (second generation) or using physical process, like solar or wind energy;
- The argument that the biofuels will be produced in degraded lands or in those that are not in use to produce food is not valid – some professionals believe that, if the land is abandoned, there is a reason for it. And usually that reason is that the soil is exhausted or is naturally poor in such a way that the investment needed for it to become productive is not economically attractive;
- Indirect land use changes (ILUC), activity-induced changes in land use that occur in the areas surrounding the place of the main biofuel production area. This process implies ecological, economic and social aspects which are hard to be identified and measured;
- The agricultural management used for biofuels production can generate negative impacts to the environment and/or for the communities around it, for instance, because of the high input of fertilizers and pesticides which become a source of soil and water contamination;
- Sustainability criteria should be applied also for exporting regions to avoid negative impacts at the original production region;
- Possible conflicts in water use can appear, since some biofuel crops and/or their subsequent processing are highly dependent on water.

3.2. Drivers of sustainable or unsustainable biofuels

Drivers include decisions, circumstances of a biophysical, socio-economic, and governance nature with relevance at field, farm and higher levels. The main drivers related to biofuel expansion are related to biophysical aspects (combination of soil type, topography and

Table 1
Expert skills selected for the interview.

Contact person	Expertise
1	Sugarcane ethanol – contributions to climate change mitigation and environment.
2	Resource Use Efficiency and Environmental Performance of Biofuel Cropping Systems
3	Development economics.
4	Agricultural systems, Grasslands, Mathematics, Nutrient balance, Nitrogen cycle, Agroecosystems, Mathematical models, Carbon cycle, Dynamic modelling, Simulation models.
5	Principles of production ecology, sustainability of biofuels.
6	Agricultural systems, Nutrient balance, Nitrogen cycle, Agroecosystems.
7	Soil quality assessment tool
8	Agro-industrial Chains, Agricultural Economics, Consumer Studies, Land Development, Marketing.
9	Agriculture in the Netherlands, Horticulture, Marketing, General Economics, Management Studies, Agricultural Economics, Arable Farming, Logistics, Food Quality and Safety
10	Agriculture in the Netherlands, Land Use Planning, Landscape Ecology, Soil Management, Knowledge valorisation.
11	Agricultural Policy, Development Sociology, Environmental Policy, Politics, Public Administration.
12	Agrotechnology, Engineering, Agro-industrial Chains, Agricultural Engineering.
13	Agricultural Policy, Climatic Change, Environmental Management, Land Degradation, Soil Fertility, Soil Management, Soil Sciences.
14	Bioenergy, Agricultural systems, Agro-industrial chains, Animal production systems, Human nutrition, Plant production systems, Tropical agriculture, Africa, Agricultural research, Agroecosystems, Change management, Tropics, Farming systems research, Food quality, Food security, Development cooperation, Innovations, Supply chain management, Sustainability, Research coordination.
15	Climate change, sustainability of biofuels.

climate codetermine potential crop production, land suitability and land availability for biofuel crops), socio-economic aspects (smallholder characteristics, crop value chain characteristics,) and governance aspects (influencing industry viability by creating demand and increasing relative market competitiveness, distributional and environmental outcomes from biofuel industries through conditional support) (Florin et al., 2014).

The market and public policies were mentioned by the interviewed as the main issues associated with drivers for biofuel production. Markets generally follow their own logic and are difficult to foresee. Public policies, in many cases, reflect national and international political agendas, and these may not always be internally consistent. The decision to review the production mode and its aspects related to gas emissions and sustainable development drew attention to biofuel production as an alternative to reduce GHG. Many countries established targets to improve the fuel blend with ethanol alongside other strategies. In Brazil, for instance, in 2003, the widespread commercial introduction of vehicles designed to run on both gasoline and ethanol, termed *FlexFuel* vehicles, overcame technological limitations related to blending and facilitated the decrease in gasoline use within the country (Buckeridge et al., 2012).

Another important driver refers to international agreements in the framework of climate change prevention and mitigation. In this new scenario, ethanol appeared as an option to replace fossil fuels and reduce GHG emissions. In Brazil, that driver for biofuel use received strong incentives by the Brazilian government through the Agroenergy National Plan public policy (MAPA, 2006). Some of the goals of this plan are to create employment expansion opportunities and income generation within agribusiness, with more participation of small farmers, to contribute to the fulfillment of the Brazilian commitment Protocol, to enable opportunities that the agreement favors for carbon sequestration credits, and to induce the creation of the international biofuel market, ensuring industry leadership in Brazil. Since the plan was launched, the sugarcane area in Brazil has increased by approximately 44% in area, which shows the importance of specific public policies as a driver for change.

3.3. Integration of sustainability aspects (social, economic and social) and trade-offs

Sustainability collates ideas of integration of social, economic and ecological interests and initiatives. However, many experiences have shown that it is not trivial. Gibson (2006) stated that the sustainability assessment design should be included into a larger overall governance regimes, with interconnections among issues, objectives, actions and effects, though the full interrelated set of activities from broad agenda settings to result monitoring and response. Regarding this statement, the sustainability should not be a choice, but an obligation. This idea is part of the sustainability assessment related to biofuel production. Probably because this field is part of international agreements related to climate change, there are many initiatives related to sustainability assessment of biofuel production, such as the Directive 2009/28/EC of the European Parliament, Cramer Index (the Netherlands), The Renewable Transport Fuel Obligation (RTFO) (United Kingdom), and others.

However, the question is: is this initiative sufficient to guarantee sustainability of biofuels? This is not an easy question. However, maybe the reflection concerning it should start from the beginning of the discussion. As soils, vegetation, water and all natural resources are valuable and currently scarce, would it be more sustainable and

Table 2
Questions used at the open interview for the expert consultation.

1	Tell me about your work with biofuels and how do your expertise contribute for biofuels sustainability assessment? How it could be included to improve it?
2	Do you think that the biofuels production, especially sugar cane, can be sustainable? Why?
3	What are the issues that could not miss in a biofuels (sugarcane) sustainability evaluation?
4	Which are the drivers that direct biofuels in a sustainable or unsustainable way?
5	Notably, there is significant amount of comprehensive studies on economic and environmental sustainability issues but social issues are still under studied in the biofuel literature. Why do you think it happens? Do you think that is important to put them together? How to integrate the sustainability aspects (social, economic and social) together?
6	Is the scale a sensitive point concerning sustainability assessment? How is possible to outline this?
7	Is multistakeholder and learning process important to be included in biofuels sustainability assessment? Who should be included in decision making processes concerning biofuels?
8	What are, in your opinion, the most relevant direct impacts f biofuels (sugarcane) impacts? And indirects?
9	How to link technical knowledge to public policies?

responsible to use these resources to produce food instead of fuels, since there are billions of people to feed? Should we take into account the cost of the impact at the ecosystem services caused by sugarcane monoculture and the high-input intensive agricultural production? Gibson (2006) summarized these issues to ensure the integration of social, economic and ecological issues. The following points were stressed:

- Redefine the driving objectives and consequent evaluation and decision criteria to focus attention on the achievement of multiple, mutually reinforcing gains;
- Provide integrative, sustainability-centred guidance, methods and tools to help meet the key practical demands of assessment work, including identifying key cross-cutting issues and linkages among factors, judging the significance of predicted effects, and weighing overall options and implications, and;
- Ensure that the decision-making process facilitates public scrutiny and encourages effective public participation.

The literature review and interviews done for this study showed that integrating all sustainability pillars in the same evaluation is a huge challenge. Most of the evaluations relate to environmental and economic dimensions of sustainability, while neglecting or downplaying the social dimension of sustainability. One option to minimize this problem of a limited and biased sustainability perspective could be to work in two ways simultaneously: one considering a general aspect related to the subject matter and another one, more specific, considering the study case. In other words, a multiscale approach. Specific indicators should be used for each approach. Gomes et al. (2016) drew attention to the fact that the establishment of evaluation systems for sustainable development requires work on the interfaces between the components of sustainability. Consequently, any kind of indicator demands grounds in good practices of construction and use. Strengths and weaknesses of the various indicators should be studied from the sustainability perspective. So, the use of robust indicators in the sustainability assessment seems essential to establish regional and sector strategies.

3.4. Scale and sustainability

Geographical scale is a factor in interactions between climate change and sustainable development, because of varying spatial dynamics of key processes and because of varying scales at which decision-making is focused (Wilbanks, 2011). Despite not having been considered the most appropriate form of analysis for ethanol, at higher scale levels, computer simulation models can be used for this purpose. Bouma et al. (2007) indicated that it is crucial to have research tools for planning high-impact projects, such as biofuels production. This is especially useful when the debate is about the implications of biofuels in climate change and GHG emission reductions, since these phenomena have a regional or even global impact that transcends the local scale of biofuel production areas. Therefore, sustainability criteria should be also applied for exporting regions to avoid negative impacts in the original production region.

However, according to the experts, for the study case of ethanol sustainability, the actions should occur in a local scale. It would be a good strategy to involve stakeholders, to realize and to understand positive and negative impacts for support policies. Thus, there was consensus that public policies for ethanol production should be proposed and implemented at local to regional scales.

3.5. Multistakeholder involvement and sustainability

Stakeholders include farmers, experts, policy-makers, researchers and other individuals, groups and organizations that are directly affected by decisions and actions or have the power to influence the outcomes of these decisions (Reidsma et al., 2011). Phrased in more general terms, stakeholders are those individuals or parties interested in a specific case. Stakeholders do not constitute a rigid group that must be present in a decision-making process, but they should be a group identified for a specific decision-making process. Stakeholder consultation is an essential element in developing, implementing and operating a biomass project. It plays a critical role in raising awareness of the project's impacts and helps to achieve agreements on the approach, management and operation of the project, whilst maximizing benefits and minimizing negative impacts. That approach could help avoiding potential conflicts, arising for example from competing claims over land use. In addition, stakeholders should be consulted for their relevant local and practical knowledge, often filling gaps in scientific knowledge (Van Der Sluis et al., 2013). Specifically concerning biofuels, Chanthawonga and Dhakala (2016) highlighted that stakeholder perceptions provide new ideas and address shortcomings of current markets and policies to promote biofuel development.

Gibson (2006) emphasised that relevant stakeholders must include represent people from sustainability-relevant positions (for example, community elders speaking for future generations) as well as those directly affected. Considering the study case of Brazilian ethanol, the stakeholders that should be consulted include community leaders in the areas of deployment of the plants, departments of agriculture, environment and planning of municipalities, and representatives from companies and from institutions that have technical and/or scientific knowledge of the area concerned. The experts indicated that stakeholder consultation should happen in the earliest stage of the negotiation because it is an important place for negotiation and knowledge about the different powers concerning the subject. On the other wide, early stakeholder involvement can also act as an opportunity to push the market for ethanol. Concerning this dilemma, the early engagement of the different stakeholders allows to better understand initial reactions about the acceptance or not of proposals on bio-ethanol. It could furthermore provide an opportunity to clarify relationships among parties. For instance, the technical and extension should be able to help the implementation of the decisions concerning political guidelines. It is different from imposing new practices for the community.

3.6. Direct and indirect impacts of LUC of biofuels

In a global economy, indirect land use change (ILUC) due to an increase in biofuel production in one country is not limited to that country alone but could occur worldwide. ILUC measurement can be challenging as its effects could be distributed across multiple regions by global trade and could occur with significant time lags. Currently methods and models are being developed to estimate ILUC impacts (Khanna and Crago, 2011). There was a consensus among the specialists that ILUC is mainly a macro-economic topic and that it is very hard to translate into requirements that can be effectively verified on a micro-economic scale (Poppens and Hoekstra, 2013). Both direct and indirect land use or land cover change due to cultivation of crops for biofuel are linked to carbon stocks and GHG emissions because different amounts of carbon dioxide are released to the atmosphere when different vegetation types are removed (Florin et al., 2014).

According to the most recent land use data for Brazil, 264 million ha of the land mass of Brazil in 2005 was agricultural land. The area covered by sugarcane represented only 2.5% of the total area. Compared to the area planted with soybeans (23 million ha), sugarcane land cover is relatively small, and mostly confined to the southeast (64%), and along the coastline in the northeast (19%) (Martinelli and Filoso, 2008). Concerning sugarcane expansion in Brazil from 1975 to 2012, it increased 413% in growing area, which represents some 7 million of hectares occupied with this crop (IBGE, 2017).

LUC impacts generally do not seem to be the main negative effect of sugarcane crops, but soil erosion, deterioration of aquatic systems, nitrogen pollution, destruction of riparian ecosystems are more important

as side effects of growing biofuel crops that have caused many problems (Fiorio et al., 2000; Politano and Pissarra, 2005; Howarth, 2005; Martinelli and Filoso, 2008). Cherubin et al. (2016a, 2016b) observed that long-term LUC from native vegetation to extensive pasture depleted overall soil quality, driven by decreases in chemical, physical and biological indicators. According to the same authors, conversion from pasture to sugarcane, in contrast, did not have significant impacts on overall soil quality, primarily, because chemical improvements offset negative impacts on biological and physical indicators. Therefore, sugarcane expansion into degraded pastureland could be a sustainable strategy to meet increasing demands for biofuels. Another issue that is clearly connected with LUC are the high logistic costs associated with sugarcane crops. Since sugarcane cannot be transported over long distances for processing, sugarcane needs to be produced close to an ethanol production facility, with distances having to be less than 100 km. Sugarcane-based ethanol production, therefore, takes place in regions having a dense paved-road network, a supply market for industrial needs (for example, machines, services, labour), and if possible, high electricity demand to allow co-generation using surplus bagasse (Sparovek et al., 2007). So, the probability of LUC promoted by sugarcane expansion is much higher in areas with the logistics structure is well organised. If one intends to stimulate the expansion of sugarcane to areas with a more poorly developed logistics structure, it would be necessary first to invest to generate those facilities.

An important aspect that appeared during the interviews is the importance to know what is being produced, who is producing and where the production is. This can be a way to map the production and identify the direct and indirect impacts of biofuels production. If the benefits are being reversed for local improvement, it could be considered a sustainability indicator.

Framework proposal to analyse sustainability of biofuels

As highlighted throughout this paper, sustainability is an essentially integrative concept and the integration among social, economic and ecological issues constitutes a major challenge that should be pursued. A framework with general guidelines for a biofuels sustainability assessment is presented (Fig. 1) and the proposal is that this framework could also be applied for other crops, since the main aim is to internalize the ideas about sustainability in agricultural production.

The first step of the development of a sustainability standard is the formulation of a mission including a sustainability definition because *without such a clear definition, it will be difficult to formulate a policy that will definitely lead to an improvement in sustainability* (Lewandowski and Faaij, 2006). The same authors emphasized that such a sustainability definition must be formulated in a context-specific way because at local level sustainability will be defined according to the priorities and the expectations of the people in their regional setting. The second step of the development of sustainability standards is the formulation of sustainability criteria and indicators to measure the performance of these criteria. The scale of the sustainability criteria development should be defined. In general, the local approach is more related to social and environmental sustainability issues while global scale is more linked with economic sustainability. Fig. 2 presents some suggestions about criteria and indicators that can be used for global and local scales. The biggest difference between both approaches is that for the local approach it is necessary to involve local stakeholder specially required to clarify what can be considered sustainable for that reality, while for the global approach, the criteria should show structural guidelines for biofuels sustainability.

The development of certification systems could be an important step towards the implementation and control of sustainable biomass trade (Lewandowski and Faaij, 2006). However, a bottom up approach is desirable, with stakeholder engagement and trade-off knowledge. These are important aspects to form clear ideas about the social impacts of biofuels, whereas often no importance was paid to this subject. Another important aspect is to insert the life cycle analysis

4. Conclusions

Policies play an important role in the development of the bio-energy trade (Lehtonen, 2011). In several countries, biomass use is promoted by national policies and incentives. The demand for bio-energy is growing due to the climate policies of various countries that search for cost-effective strategies for the reduction of greenhouse gas emissions. The expansion of biofuels is one of the actions that result from these public policies, as a strategy to reduce GHG emissions and to fulfil for the country concerned the international agreements.

Generally, our observations indicated that environmental and, especially social, dimensions of sustainability are very poorly evaluated concerning ethanol production. Most analyses are focused on economic

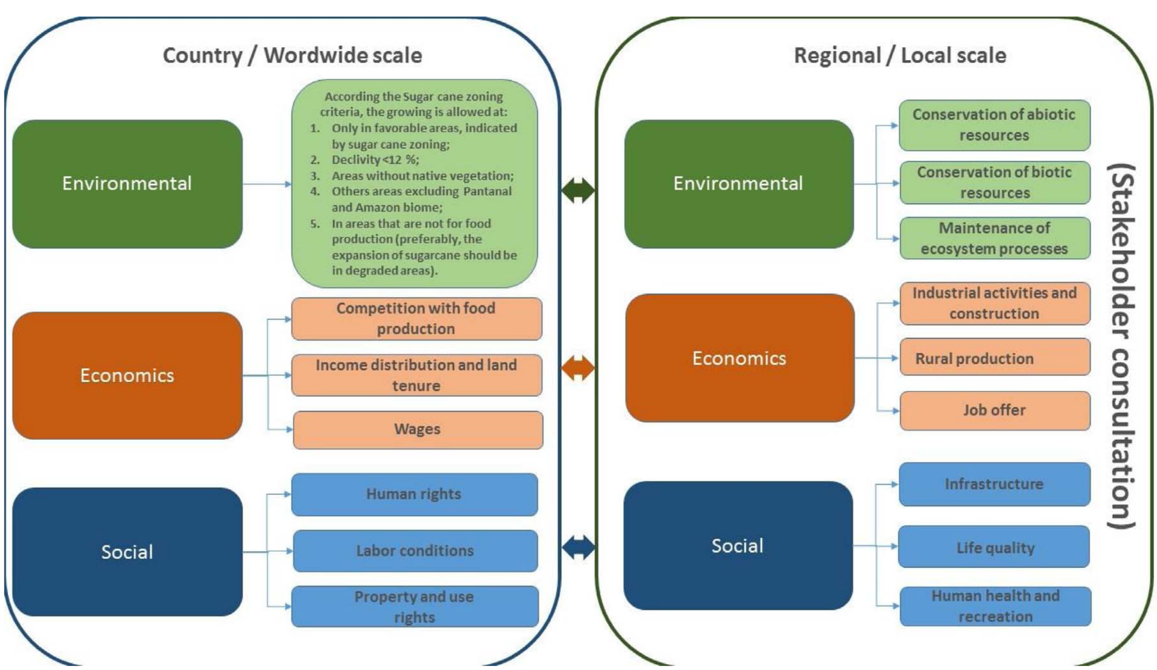

Fig. 1. General guidelines for a framework for a biofuels sustainability assessment.

aspects, which is very sensitive, as the market is vulnerable to food prices. Then, most of the times, a chain impact values are observed: food price affect biofuels production and both affect people. Moreover, this is the reason why the stakeholder process plays an important role in this subject. However, the definition about stakeholders is not as easy as it seems. Especially in the sugar cane case in Brazil, where it affects both small and big farmers. Those farmer groups do not have the same interests, and their interests are furthermore represented by different ministries (cf German et al., 2011; Frate and Brannstrom, 2015). Therefore applying social sustainability indicators inevitably involves political decisions. The goal is to develop a democratic process – which is essential to sustainability – and establish a set of sugar cane sustainability criteria that could be used in any case. It seems to be the best way to understand the whole biofuel chain.

There is a simple question that could be answered to reach sustainability: where is the income generated locally going? Can the biofuel value that is created locally be kept locally? This simple (rhetorical) question has a simple answer, especially when the focus is on small farming (Hodbod et al., 2015). The projects about sugar cane should be intended to improve locally the communities that produce the sugar cane through policy incentives. The main problem regarding linking policy and science is how to do it. There is a gap of tools to optimize this linage. For instance: for the industries, business in general there are many tools that can enable this link, like contracts, agreements, etc. But this kind of regulation is much harder concerning policies.

In order to bring stability to the biofuel production, it is necessary to insert the government hands to subsidise production and keep the prices competitive. Should we leave the production to follow market flows, we may greatly increase the risk. However, it is important to highlight that government subsidies can create both sustainable and unsustainable systems, in different aspects.

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